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SINGLE CURVED vs. DOUBLE STRAIGHT JETTIES.

AN APPLICATION OF NATURAL LAWS TO THE REMOVAL OF BARS.

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Vibration is fundamental to the transmission of energy. Heat, light, sound and electricity are propagated by waves of different intensities.

The vibrating pendulum or hairspring marks time; the oscillating piston turns the crank; the vibrating diaphragm transmits the voice. Molecular oscillation within variable limits is a well-recognized law of Nature, even in the transmission of stresses through solids. In fluids it is more discernible in the particles themselves. Hail, snow, dust, sand or rain, driven by wind, seldom pursue a straight course. The path of a storm-center is generally a curved line, while the motion of its elements is in the nature of a cycloid. A river never takes the shortest line to the sea, but oscillates wherever possible, from bank to bank, carving its bed of pools and shoals in such manner as to check and regulate its otherwise destructive energy.

No stream pursues a straight course if it can possibly avoid it, but swings gracefully from side to side, cutting first on the right then on the left, but always on the concave bank, and depositing on the elbows and crossings or points of inversion. Neither do the filaments of the stream pursue parallel paths. The maximum velocity is found near the mid-area of the section, but if these particular particles were to continue uninterruptedly along this course of maximum velocity they would run away from the rest of the water and leave a void. This tendency is checked by a constant interchange of position of the particles which restores the equilibrium by swirls and eddies, cross, and even back currents, in certain sections. It not infrequently happens that water runs up hill, as in the case of a flood when the crest of the wave gives a reverse slope up stream. Such are a few of the

phenomena of flowing bodies, which are well recognized and understood by navigators or others who are familiar with streams flowing between banks; and precisely the same conditions characterize streams in the ocean or other large bodies of water.

Numerous illustrations of this law of running water are within reach of every one.

Every map of the rivers of any country, and especially in alluvial plains; every chart of ocean currents or of tidal estuaries, shows this law to be universal.

The huntsman, fisherman, navigator or traveler on waterways will recall apt illustrations of this law of running water and knows that the deepest water is on the concave side of the bend and not in the cut-off. So true is this, that a pilot navigating a river of which he has no chart invariably hugs the concave banks, swinging from side to side, and is only in doubt as to the channel in the straight reaches between bends.

The drainage rivulets to oceans, lakes or ponds, as they flow across the strand, pursue a serpentine course and not a straight line. The same features are found in the delta mouths of rivers and their passes, which are not straight but which oscillate with variable radii to the sea.

These phenomena have been recognized by some of the most experienced hydraulic engineers of the continent in the treatment of their interior waterways with excellent results.

The following extracts may serve to emphasize the necessity for a close study of this subject on the part of those interested in the development of our commercial highways.

Wheeler, in his "Tidal Rivers," says: "In carrying out works for the improvement of channels in sandy estuaries, it will be found much less costly and more effective to direct and develop the one main low-water channel than to attempt to make a straight channel in a new direction by training regardless of existing circumstances." * * * "By attempting to drive a channel through sands in a direction which nature has not selected will be found costly to carry out and difficult to maintain."

* * * "Straight reaches are not found in practice to preserve the same uniformity of depth as curved channels under the varying conditions of flow to which they are subject."

"In a curved channel the greater velocity and scouring action of the stream is concentrated on one side, preventing deposit altogether, or causing it to accumulate on the convex side only, leaving the greater part of the bed of the river at its full navigable depth.

"A concave bank sets up a scouring action in the current by diverting the particles of the water from their straight course, causing that rotary motion and boring action which occurs in all bends, and which operates in deepening the channel along the concave side.

"From observations made by Mr. H. C. Ripley it was found that in a natural river the water was 58 per cent. deeper in the curved portion of the channel than in the straight reaches.

"Mr. Stevenson says: As a purely abstract question, he, however, was of opinion that it might safely be affirmed that a stream is most likely to follow a permanent course when directed by a concave bank; that the centrifugal force in curved channels has a tendency to draw the greater portion of the water to the concave side, and that the greatest scouring power will be found on that side; whereas in a channel directed by straight walls, the current, having no such bias for either side, is more easily thrown across from side to side.

"Mr. Scott-Russel, in pointing out the evils which had arisen from the abrupt interpolation of portions of straight cuts into gently winding rivers, expressed the opinion that to make part of a natural river straight was a dangerous undertaking; that where the curves were gentle the natural bends should not be interfered with; that a river has an oscillating motion, and there is a similar process going on in it to that which goes on in a pendulous body. A pendulum set in motion continues to oscillate isochronously without the expenditure of any new force, and in like manner, if once a curve or bend was established in a river with considerable current, the mere fact of the commencement of curvature would give it a tendency to continue that curvature, and the stream would go on oscillating regularly to the sea in curves of opposite curvature. Continuity of a system of oscillation should therefore be maintained.

"Captain Culver, speaking of the improvement of rivers, says that straight reaches are strictly to be avoided, more particularly where there is an established business upon the banks of the river to be trained. With a straight reach the deep-water track is acted upon by the most trifling causes, ranging from side to side at will, and it follows that under these circumstances there is no security whatever for the permanency of the deep water, either in a fixed channel or at the shipping berths.

"The commission of engineers employed by the French government to report as to the improvement of the navigation of the estuary of the Seine, in recommending the extension of the training walls through the estuary down to Honfleur, advised that these should assume a sinuous form, having a concave bend leading to the entrance to Honfleur harbor, in order that deep water should be maintained at the entrance jetties.

"M. Fontain, in designing work for the rectification of the Rhine, avoided straight cuts and adopted curves. In the determination of the radii of curvature, he was guided by the inclination and force of the current. General Eads also adopted a curved form for the jetties for the South pass of the

mouth of the Mississippi. In the Weser no attempt has been made to straighten the channel, the existing curves being eased and improved. By cutting off abrupt bends, contracting the width where too great, fixing the course through sands, and deepening where required, a channel may be brought into a uniform condition with a series of gentle curves and rendered serviceable for navigation at far less cost and with better results than by making an entirely new cut. The course may not be so direct in the former as in the latter case, but the want of directness will probably be fully balanced by the more permanent maintenance of a uniform depth throughout, and the greater scouring power of the ebb and flood water."

"The effect derived from training takes time to develop, and the full benefit of the deepening is seldom felt until a considerable period after the work is completed. The benefit to navigation is more quickly realized when the deepening is also assisted by dredging, not only by the actual material removed by the dredger, but also by the disturbance of the material by the buckets assisting its transport by the water.

"Tidal currents will, without any aid from training, keep to the same channel if sufficiently deep. The tendency of all flowing water is to run along the line of the deepest channel, especially if that line is in the direction most favorable for the run of the flood and ebb."

When it comes to the application of these principles, they are so frequently violated with us as to cause a doubt as to whether they are really recognized as fundamental.

To violate a physical law is to cause an injury which can be repaired only at considerable loss by the application of a counter irritant. Nature will constantly seek to restore normal conditions. It is surprising to find mathematical principles so frequently misapplied to physical problems. Because "a straight line measures the shortest distance between two points" it does not follow that two parallel straight lines with currents between them will be better as training walls for a navigable channel than a single curved jetty which aids those currents to carve out and maintain their own channel. Yet it is the almost invariable practice to build two such parallel *straight* jetties or to dredge *straight* cuts in rivers which soon refill and require constant expense for maintenance. At least three times has the cut through the "Cherry Island Flats" in the Delaware river, two miles long, been dredged to 26 feet, mean low water, and just as frequently has it filled almost immediately after, to its ruling depth of 19 feet.

The concave bank practically controls and directs the stream—it is the point of attack for the currents and the point where scour is most rapid. The convex bank is the reciprocal of that where there is virtually no current and where deposit takes place. The continuous change of direction caused by the resistance or reaction of the concave bank, and the consequent differences of velocity of the fluid-particles before and after impart, cause a latteral bottom movement which carries the silt across and on to the convex bank, thus maintaining a deep channel under the concave bend; the depth increasing with the sharpness of the turn.

By maintaining these oscillations by the erection of artificial banks or reaction-jetties across ocean bars the channel may be quickly and cheaply created by natural processes; but great care must be taken in adjusting their curvature and location to the requirements of the particular site, for if placed on the wrong side of the channel with respect to the littoral drift at inlets, they will result in failure.

Thus, a single structure may be made to produce its counterpart, or convex training-bank, which will be automatically adjusted to the regimen of the currents, whether tidal or fluvial, at less than half the cost of the parallel straight jetties, and give a far better and more permanent result, requiring a much smaller expenditure for maintenance.

Such a result has actually been secured at Aransas Pass, Tex., a purely tidal inlet, by an incomplete jetty detached from the shore and placed on the windward side of the channel, as designed by the writer, and the same principles may economically be adapted to the opening of the delta mouths of silt-bearing streams by single concave reaction jetties to better advantage than by two parallel or convergent jetties. Such designs would appear to conform to the laws of flowing bodies, and would not do violence to nature, but, on the contrary, assist her operations.